Pedobiologia, Bd. 17, S. 262—282 (1977)

Wye College (University of London), Ashford, Kent England

The effects of compaction of agricultural soils on soil fauna

I. Field investigations

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With 2 figures

(Accepted: 11. 9. 1976)

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1. Introduction

Although the effects of compaction of agricultural soils on crop yields, root growth and form and the physical characteristics of compacted soils have been investigated (e. g. summarised in Gooderham 1973, El-Karouri 1974, Aritajat 1975) little work has been done on the effects of soil compaction on soil fauna.

The main purpose of this study was to investigate the effects of agricultural soils compacted by a tractor on soil fauna. Two different types of soil, silt loam and clay, were compacted and the soil fauna recovered at intervals and identified. The effects of loosened silt loam soil on the fauna were also found. The effects of different soil compaction stresses at different water contents on soil fauna in the laboratory were studied and will be reported later (Aritajat, Madge and Gooderham 1977).

2. Materials and methods

2.1. Experimental sites

Two sites with contrasting soil textures were chosen on the farm at Wye College. The first site is situated in Woodfield VI, on silt loam (Wood series; Green and Fordham 1973), under grass. The previous cropping history was as follows: 1969 beans, 1970 wheat, 1971 oats, and 1972 perennial rye grass. The second site is located in Files, on clay (Wicken series; Green and Fordham 1973), also under grass. The previous cropping history was as follows: 1970 wheat, 1971 barley, and 1972 perennial rye grass.

1) Present address: s. page 281.

In December 1973 four rectangular plots, measuring 3 × 10 m each, were laid out on the silt loam site. The soil was compacted by driving a tractor (Massey Ferguson 165, weighing approximately 2100 kg) over the whole area of two plots, once and ten times respectively. The compaction stress applied to the soil depends on tyre inflation pressures, and these were 1.8 and 0.8 bar (kgf/cm² resp. kp/cm²) for front and rear wheels respectively. The soil moisture content at the time of applying the treatment was 25 g/100 g. In a third plot the soil was loosened by rotary cultivation to a depth of about 8 cm. A fourth plot was left untreated, and acted as a control.

In October 1974 three rectangular plots, measuring 2 × 16 m each, were laid out on the clay site when the soil moisture content was 45 g/100 g, and treated similarly to the silt loam site, except that the soil-loosening treatment was omitted.

2.2. Sampling procedures

Sampling procedures for soil athropods and earthworms were used as follows:

(1) The arthropod soil fauna from the silt loam grassland were sampled one day before treatment, on 12th December, 1973, and then at intervals of two weeks, one month, three months, six months and nine months following treatment. Soil fauna from the clay grassland were sampled four days before treatment, on 6th October, 1974, and also at intervals of two weeks, one month, three months and six months after treatment. On each sampling occasion twelve random samples were taken from each treatment plot at the same time of day.

Soil cores (10 cm diameter × 7.5 cm deep) for extracting soil fauna were collected with an auger consisting of a stainless steel cylinder, 10 cm in diameter and 15 cm in height, with an inner plunger mechanism mounted in a rectangular cross-sectioned thrust mechanism 66 cm long, and made of 2.6 × 0.6 cm bright steel (Clutterbuck 1974). The plunger mechanism allowed the soil sample to be removed from inside the metal cylinder without damaging the sample. The samples were all loaded into the extraction apparatus within six hours of removing them from the sampling areas.

(2) Earthworms were recovered by using the formalin technique. On 7th April, 1974 and 1st October, 1974, that is, four months and ten months after treatment, four 0.09 sq m quadrants were marked out in each treatment of the silt loam site after the vegetation had been cut close to the soil surface and removed. Each quadrant received three successive applications of 0.5 litre of a 0.66 per cent formalin solution (30 ml of 40 per cent formalin in 4.56 litres water applied to 0.09 m² of soil surface; Madge and Sharma 1969). Emerging worms were collected for up to 30 minuter after the last formalin application and preserved in 5 per cent formaldehyde solution. Twenty-four hours later the worms were counted and weighed. Earthworms were similarly collected from the clay soil site on 25th April, 1975, that is, six months after treatment.

2.3. Extraction apparatus

(a) The apparatus used was a slightly modified version of the heat extraction (Tullgren) apparatus currently used at Rothamsted Experimental Station, and was constructed and previously used at Wye College by Clutterbuck (1974) for studying the effects of herbicides on soil fauna.

The apparatus consists of a cabinet (250 × 64 × 30 cm) containing 60 extraction units. Each extraction unit conists of a hollow sample container (10 cm diam. × 7.6 cm deep) made of anodized aluminium, fitting flush with the cabinet surface. Each unit is fixed directly above an anodized aluminium funnel, 24 cm high × 14 cm top diameter, tapering to one cm diameter. The soil core rests on a stainless steel gauge mesh (mesh 2.82 mm).

A steep temperature gradient was set up and maintained in the soil samples by a heating unit above and an insulated cooling cabinet below, with air circulating throughout the cabinet by means of a cooling unit.

The soil samples in the sixty extractor units were heated from above by sixty 40-watt light bulbs mounted in a moveable insulated lid. During extraction, the lid was lowered so that each lamp was fixed 2 cm above each soil core. The lamps were connected to an external variable rheostat and the light intensity (heat) controlled manually.

The cooling unit was mounted in the centre of the insulated cabinet on anti-vibration material and operated by a 0.2 H. P. cooling unit mounted externally below the apparatus. During extraction, two small fans circulated cool air inside the cabinet. The temperature inside the cabinet was maintained at 10 ± 0.5 °C by thermostats within the cabinet. The fans continued to circulate air when the cooling was cut out so as to maintain an even temperature throughout the cabinet. Long, narrow evaporation trays (sponge-filled drain pipes) were fitted inside the insulated cabinet which kept the relative humidity at about 80 per cent; external dropper bottles kept the trays filled with water. A hygrometer was mounted inside the cabinet and could be viewed through a glass porthole in one side of the cabinet.

Close fitting collection tubes (1.7 × 5.2 cm) were fixed to the narrow ends of funnels projecting under the cabinet by clip hooks. Each tube was one-third filled with a mixture of 70 per cent ethyl alcohol and 5 per cent glycerol.

(b) In preliminary experiments, the efficiency of the air-conditioned extraction apparatus (above) was compared with that of a conventional modified Salt and Hollick (1944) flotation apparatus[1]). The soil sample was first soaked for one hour in warm water, then lightly crumbled by hand and washed through the sieves of the apparatus. The remaining debris, including soil fauna, was collected and suspended in a saturated solution of magnesium sulphate, the solution filtered, the fauna and debris collected and separated in water and xylene, and the fauna finally recovered and examined.

2.4. Extraction method

The surface vegetation of each soil core was first clipped close to the soil surface, inverted samples then placed at random in the sample containers and collection tubes fitted to the funnels. The cooling unit was turned on and left for twenty-four hours to ensure that extraction started at the same temperature (10 °C) irrespective of the external laboratory temperature. The heating unit was then switched on and the soil surface temperature increased at regular intervals from 10 °C to 45 °C over eight days, the temperature in the cooling cabinet being maintained at about 10 °C. When the temperature reached 45 °C, extraction was continued for a further six days. The extraction procedure on each sampling occasion thus lasted fourteen days.

2.5. Soil physical measurements

Undisturbed soil cores (replication = 12) were taken from the plots with a core sampling tool at two depths (0—7.6 cm and 7.6—15.2 cm), on five occasions on the silt loam site and on four occasions on the clay site. The last samplings of the silt loam and clay sites were carried out at nine and six months respectively after application of the treatments. The following physical properties were determined for each core sample: bulk density (g/cm^3), soil moisture (g/100 g) and air porosity (cm^3/100 cm^3). Soil mechanical resistance (bar, or kgf/cm^2) was also measured (replication = 20), using a field penetrometer (manufactured by Leonard Farnell & Co. Ltd., North Mymms, Hatfield, Herts.) with an 8 mm probe.

3. Results

3.1. Preliminary experiments

3.1.1. *Efficiency of the air-conditioned apparatus with time*

Ten soil cores were taken from each untreated (control) site on the same day on two separate occasions and the fauna extracted in the air-conditioned apparatus. The arthropods were recovered each day for 12 consecutive days, using a different set of collecting tubes each day. The fauna were separated from the soil debris in a saturated solution of sodium chloride (Madge 1969) and identified. Further soil samples were also taken on the same day on each occasion, and their moisture content determined after oven-drying.

Generally, the soil arthropods were recovered sooner from dry soil than from moist soil (Aritajat 1975). Thus, for silt loam soil with an average moisture content of 14.6 and 17.7 g/100 g most of the fauna were recovered after seven and ten days respectively. For clay soil with an average moisture content of 16.3 and 38.5 g/100 g, most of the fauna were recovered after ten and twelve days respectively.

Numbers of Acari and Collembola generally followed a bimodal distribution pattern during extraction. The early peak probably corresponded to the fast-moving, heat-sensitive species living near the soil surface, and the later peak probably corresponded to the slower-moving, relatively heat insensitive species living in the deeper soil layer, and also possibly to newly-hatched individuals during extraction. Attempts were not made to identify the two groups of soil fauna.

3.1.2. *Comparison between the efficiency of the air-conditioned apparatus and the modified flotation apparatus*

Twenty soil cores were taken from the untreated (control) plot in each site on two occasions (29th April, 1975 and 8th June, 1975). Ten cores from each site were extracted by the funnel method and ten cores extracted by the flotation method and the fauna recovered and identified.

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1) Obtainable from Burkard Scientific (Sales) Ltd., Rickmansworth, Herts, England.

The mean numbers of total soil fauna, Acari, Mesostigmata, Prostigmata and Collembola, including most of the families identified from these groups, extracted from both the silt loam and clay grasslands, were significantly higher using the air-conditioned extractor than using the soil washing extractor. Differences between the total numbers of Cryptostig mata, Achipteriidae, Onychiuridae, other Insecta and Myriapoda in both sites extracted by each method were not significant. Only the mean number of Pelopsidae (Cryptostigmata) recovered from both sites by the soil washing process was significantly higher than that recovered By the funnel method. From the results obtained it is apparent that generally the air-conditioned extracting apparatus was appreciably more efficient than the flotation method for extracting soil fauna in the sites studied.

3.2. Soil population characteristics

The overall soil arthropod density in the silt loam grassland and clay grassland sites was estimated as 29,618 per m^2 and 17,411 per m^2 respectively. These relatively low values are probably accounted for by the fact that the grassland in both areas had been recently seeded. However, direct comparisons with other investigations in similar areas (summarised in ARITAJAT 1975) are meaningless owing to the differing extraction methods, vegetation, soil type and sampling dates.

Tables 1a and b give the density of soil fauna in the silt loam and clay grasslands. In the silt loam grassland (table 1a) the lowest population of soil fauna occurred in March and highest in June. The Acari reached their lowest numbers in December and highest in June. The Collembola attained their highest population in December and lowest in March. The lowest population of other Insecta were recovered at the beginning of December and the highest at the end of December. Myriapoda were infrequent in late December and January but increased by June and September.

Table 1a. Densities, expressed as numbers/m^{2*}, of fauna in silt loam grassland soil (mean of 12 replicates)

Group	Control treatment						
	12/12/73	two weeks 26/12/73	one month 25/1/74	three months 16/3/74	six months 15/6/74	nine months 16/9/74	Grand mean
Acari	10,621	15,239	13,216	12,491	36,646	20,441	18,109
Collembola	16,816	20,848	7,721	2,989	9,960	6,131	10,774
Other Insecta	356	929	903	572	611	369	623
Myriapoda	89	38	38	102	293	293	142
Total soil fauna	**27,882**	**37,054**	**21,878**	**16,154**	**47,510**	**27,284**	**29,618**

* count × 127.2

Table 1b. Densities, expressed as numbers/m^{2*}, of fauna in clay grassland soil (mean of 12 replicates)

Group	Control treatment					
	6/10/74	two weeks 24/10/74	one month 6/11/74	three months 7/1/75	six months 7/4/75	Grand mean
Acari	16,256	8,433	14,132	9,896	14,984	12,740
Collembola	5,355	2,900	2,913	4,287	4,719	4,035
Other Insecta	738	433	979	483	318	590
Myriapoda	38	64	51	38	38	46
Total soil fauna	**22,387**	**11,830**	**18,075**	**14,704**	**20,059**	**17,411**

* count × 127.2

The clay grassland (table 1b) generally had a lower population of soil fauna compared with the silt loam grassland. The Acari and Collembola reached their highest numbers at the beginning of October and lowest numbers at the end of October and early November. Other Insecta reached their highest numbers in November and lowest numbers in April. The population fluctuation of Myriapoda was inconsistent.

In this study, the Acari: Collembola ratio was 1.7: 1.0 in silt loam grassland (table 2), whereas CLUTTERBUCK (1974) in a similar type of soil found an Acari: Collembola ratio of 2.3: 1.0. In clay grassland, the Acari: Collembola ratio was 3.2: 1.0 (table 2).

A total of 50 taxonomic groups were identified (see Appendix), including nine families of Mesostigmata, eight families of Prostigmata, six families of Cryptostigmata and five families of Collembola.

In the silt loam site (table 3) the dominant groups were *Isotoma notabilis* (61 per cent of total Collembola), *Isotoma viridis* (17 per cent of total Collembola), Eupodidae (27 per cent of total Acari) and Scutacaridae (20 per cent of total Acari). Entomobryidae, Eviphididae, Pyemotidae and Scheloribatidae were also relatively frequent.

In the clay site (table 3) the dominant groups were *Isotoma notabilis* (42 per cent of total Collembola), *Isotoma viridis* (42 per cent of total Collembola), Pyemotidae (41 per cent of total Acari) and Pelopsidae (15 per cent of total Acari). Sminthuridae, Eupodidae and Oppiidae were also relatively frequent. Thus, in the present study the silt loam soil had three dominant arthropod groups and the clay soil had two dominant groups. Both areas had two common species of isotomids.

On permanent silt loam grassland CLUTTERBUCK (1974) found that *Isotoma viridis*, *Isotoma notabilis*, Eupodoidea, the Scheloribates/Liebstadia/Hemileus group, *Punctoribates punctum*, *Minunthozetes semirufus* and *Scheloribates laevigatus* were the dominant groups. Pyemotidae and Sminthuridae were occasionally recovered. SHEALS (1957) found that three species of *Isotoma* constituted nearly 60 per cent of the total Collembola in grassland soil.

3.3. Effects of compaction on soil fauna

3.3.0. *Prefactory note*

Tables 4—19 summarise the effects of soil compaction on different sampling occasions in the silt loam and clay grassland areas over several months.

The factors involved in this analysis can be classed into two categories. (i) Interdependent factors, including those caused by herbage changes and the effects of open ground on soil fauna; (ii) independent factors, including direct and indirect effects of compaction and seasonal effects. Direct effects of compaction can reduce soil animals not adapted to withstand the altered conditions. Indirect effects of compaction result from changes in soil physical properties, bulk density, soil moisture, air porosity and mechanical strength.

The results were analysed statistically by the completely randomized method and computed using a one-way analysis of variance.

Table 2. Composition of the arthropod fauna in silt loam and clay grasslands, based on seventy-two and sixty samples respectively, over nine and six months

	Silt loam grassland		Clay grassland	
Acari	10,309	*61.22%*	6,042	*77.33%*
Collembola	6,083	*36.13%*	1,902	*23.09%*
Other Insecta	359	*2.13%*	275	*3.34%*
Myriapoda	88	*0.52%*	20	*0.24%*
Total	**16,839**	*100.00%*	**8,239**	*100.00%*

Table 3. Total numbers and relative abundance of Collembola and Acari from silt loam grassland soil, from seventy-two samples taken over nine months, and from clay grassland soil, from seventy-two samples taken over six months

	Silt loam grassland		Clay grassland	
	Total numbers	Relative abundance (%)	Total numbers	Relative abundance (%)
Collembola				
Isotoma notabilis	3,681	*60.51*	805	*42.32*
Isotoma viridis	1,034	*17.00*	795	*41.80*
Isotomidae	4,730	*77.76*	1,650	*86.75*
Onychiuridae	204	*3.35*	33	*1.74*
Entomobryidae	695	*11.43*	24	*1.26*
Sminthuridae	450	*7.40*	147	*7.73*
Poduridae	4	*0.06*	48	*2.52*
Grand totals	**6,083**	*100.00*	**1,902**	*100.00*
Mesostigmata				
Parasitidae	801	*7.77*	629	*10.41*
Rhodacaridae	754	*7.31*	238	*3.94*
Eviphididae	1,124	*10.90*	250	*4.14*
Ameroseiidae	37	*0.36*	5	*0.08*
Pachylaelapidae	7	*0.07*	5	*0.08*
Uropodidae	15	*0.10*	162	*2.68*
Total Mesostigmata	**2,738**	*26.56*	**1,289**	*21.33*
Prostigmata				
Eupodidae	2,739	*26.57*	333	*5.51*
Scutacaridae	2,022	*19.61*	28	*0.46*
Pyemotidae	873	*8.47*	2,474	*40.95*
Tarsonemidae	440	*4.27*	157	*2.60*
Bdellidae	19	*0.18*	3	*0.05*
Rhagidiidae	273	*2.65*	17	*0.28*
Tydeidae	80	*0.78*	22	*0.36*
Erythraeidae	10	*0.10*	1	*0.02*
Total Prostigmata	**6.456**	*62.63*	**3,035**	*50.23*
Cryptostigmata				
Scheloribatidae	655	*6.35*	11	*0.18*
Pelopsidae	34	*0.34*	918	*15.19*
Oppiidae	67	*2.75*	573	*9.48*
Achipteriidae	35	*0.65*	169	*2.89*
Mycobatidae	—		4	*0.07*
Oribatulidae	—		3	*0.05*
Galumnidae	1	*0.01*	1	*0.02*
Total Cryptostigmata	**1,042**	*10.10*	**1,679**	*27.79*
Astigmata	73	*0.71*	39	*0.65*
Grand totals	**10.309**	*100.00*	**6,042**	*100.00*

3.3.1. *Silt loam grassland*

3.3.1.1. Pretreatment (December 12th, 1973)

The pretreatment samples indicated some variations between plots before compaction. In the pretreated loosened soil plot these were significantly lower numbers ($P = 0.05$) of total soil fauna (table 4), highly significantly lower numbers ($P = 0.01$) of Prostigmata (table 7) and lower, but not significant, numbers of Collembola (table 9) compared with the control. In contrast, numbers of Cryptostigmata (table 8) in the pretreatment loosened soil plot were significantly higher ($P = 0.05$) than in the control plot. Numbers of other Insecta (table 9) in the pretreated ten times compacted plot were significantly highert ($P = 0.05$) than in the control plot. The soil fauna in all other pretreatment plots were not significantly different compared with the control plot.

Table 4. Effects of compaction on population and recolonization of total soil fauna in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	219.2	291.3	172.0	127.0	373.3	214.0
1 × compaction	269.3 n. s.	180.4*	233.8 n. s.	155.8 n. s.	471.8 n. s.	224.4 n. s.
10 × compaction	235.8 n. s.	31.8***	79.1*	75.4 n. s.	411.9 n. s.	139.1*
Loosened soil	72.9*	68.6***	46.9*	64.8*	383.8 n. s.	148.2*
S. E. of mean	56.9	35.9	33.8	20.5	49.7	21.6
F.	2.60 n. s.	10.68***	6.41**	4.42**	0.79 n. s.	4.13*
L. S. D. (P = 0.05)	162.3	102.4	96.5	58.4	141.8	61.7
Total (n = 48)	**9566.0**	**6865.0**	**6382.0**	**5075.0**	**19,690.0**	**8708.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 5. Effects of compaction on population and recolonization of Acari in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	83.5	119.8	103.9	98.2	288.1	160.7
1 × compaction	89.8 n. s.	101.4 n. s.	139.2 n. s.	97.3 n. s.	390.8 n. s.	163.0 n. s.
10 × compaction	89.3 n. s.	24.2***	44.0*	39.4**	334.0 n. s.	112.6 n. s.
Loosened soil	60.4 n. s.	47.8***	33.4*	38.3**	301.3 n. s.	108.2 n. s.
S. E. of mean	12.9	11.5	18.8	14.1	37.9	18.9
F.	1.15 n. s.	15.05***	7.12**	5.80**	1.46 n. s.	2.43 n. s.
L. S. D. (P = 0.05)	36.9	32.9	53.6	40.3	108.0	53.8
Total (n = 48)	**3877.0**	**3518.0**	**3846.0**	**3278.0**	**15,771.0**	**6425.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 6. Effects of compaction on population and recolonization of Mesostigmata in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	28.7	41.3	35.1	29.1	55.1	40.7
1 × compaction	30.2 n. s.	30.0 n. s.	53.2 n. s.	33.6 n. s.	67.2 n. s.	50.1 n. s.
10 × compaction	27.1 n. s.	6.3***	7.5*	7.7**	35.5*	26.1 n. s.
Loosened soil	33.9 n. s.	18.0**	10.8*	15.0*	65.8 n. s.	34.0 n. s.
S. E. of mean	6.3	5.6	8.4	4.3	6.6	5.4
F.	0.22 n. s.	7.37***	6.59***	7.76***	4.85**	3.52*
L. S. D. (P = 0.05)	17.9	15.9	23.9	12.4	18.9	15.5
Total (n = 48)	**1438.0**	**1148.0**	**1279.0**	**1024.0**	**2682.0**	**1776.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 7. Effects of compaction on population and recolonization of Prostigmata in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	50.9	73.4	64.2	64.9	172.6	112.0
1× compaction	55.3 n. s.	65.6 n. s.	75.3 n. s.	61.0 n. s.	269.8**	103.7 n. s.
10× compaction	54.4 n. s.	14.7***	29.4*	24.7*	207.2 n. s.	63.3*
Loosened soil	15.2**	18.3***	17.8**	18.5*	124.8 n. s.	61.6*
S. E. of mean	7.5	7.0	10.5	12.4	22.2	15.3
F.	6.67***	18.72***	6.84***	3.75*	7.51***	2.93*
L. S. D. (P = 0.05)	21.3	20.1	29.9	35.5	63.5	43.5
Total (n = 48)	**2109.0**	**2049.0**	**2240.0**	**2029.0**	**9292.0**	**4026.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 8. Effects of compaction on population and recolonization of Cryptostigmata in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/75	16/9/74
Control	4.1	5.0	4.7	4.2	60.4	8.0
1× compaction	4.4 n. s.	5.8 n. s.	10.8 n. s.	2.8 n. s.	62.3 n. s.	9.3 n. s.
10× compaction	7.8 n. s.	4.3 n. s.	7.1 n. s.	3.8 n. s.	91.3 n. s.	23.2*
Loosened soil	11.3*	11.6*	4.8 n. s.	12.1*	110.8*	12.6 n. s.
S. E. of mean	1.9	1.8	2.2	2.3	17.0	3.4
F.	3.12*	3.42*	1.75 n. s.	3.59*	2.03 n. s.	4.06*
L. S. D. P = 0.05)	5.5	5.1	6.2	6.5	48.6	9.8
Total (n = 48)	**332.0**	**321.0**	**327.0**	**273.0**	**3897.0**	**623.0**

n. s. = not significant
* P = 0.05

Table 9. Effects of compaction on population and recolonization of Collembola in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	132.2	163.9	60.7	23.5	78.3	48.2
1× compaction	173.3 n. s.	72.5*	84.6 n. s.	52.5 n. s.	70.3 n. s.	55.3 n. s.
10× compaction	139.9 n. s.	5.3**	32.4 n. s.	28.9 n. s.	68.2 n. s.	22.7*
Loosened soil	6.8 n. s.	15.3**	6.7 n. s.	18.8 n. s.	60.0 n. s.	42.8 n. s.
S. E. of mean	48.0	26.9	19.6	10.2	16.1	7.5
F.	2.32 n. s.	7.30***	2.99*	2.15 n. s.	0.22 n. s.	3.45*
L. S. D. (P = 0.05)	136.9	76.8	55.8	29.1	45.8	21.5
Total (n = 48)	**5425.0**	**3083.0**	**2212.0**	**1484.0**	**3320.0**	**2027.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 10. Effects of compaction on population and recolonization of other Insecta in silt loam grassland soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	2.8	7.3	7.1	4.5	4.8	2.9
1× compaction	5.1 n. s.	5.7 n. s.	9.4 n. s.	5.5 n. s.	6.3 n. s.	2.5 n. s.
10× compaction	6.5*	2.3*	2.4*	7.1 n. s.	6.1 n. s.	1.6*
Loosened soil	5.4 n. s.	3.6 n. s.	5.5 n. s.	6.8 n. s.	7.7 n. s.	1.7 n. s.
S. E. of mean	0.9	1.4	1.2	1.4	1.1	0.5
F.	3.47*	2.64 n. s.	6.53***	0.76 n. s.	1.17 n. s.	2.03 n. s.
L. S. D. (P = 0.05)	2.4	3.9	3.3	3.9	3.2	1.3
Total (n = 48)	**237.0**	**227.0**	**293.0**	**286.0**	**298.0**	**104.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 11. Effects of compaction on population and recolonization of Myriapoda in silt loam grass land soil (mean of 12 replicates)

Treatment	Pre-treatment	After treatment				
		two weeks	one month	three months	six months	nine months
	12/12/73	26/12/73	25/1/74	16/3/74	15/6/74	16/9/74
Control	0.07	0.3	0.3	0.8	2.3	2.3
1× compaction	1.1 n. s.	0.8 n. s.	0.7 n. s.	0.4 n. s.	4.4 n. s.	3.7 n. s.
10× compaction	0.4 n. s.	0.1 n. s.	0.3 n. s.	0.0*	3.7 n. s.	2.3 n. s.
Loosened soil	0.3 n. s.	1.9 n. s.	1.3**	1.0 n. s.	14.8**	4.5*
S. E. of mean	0.3	0.5	0.2	0.3	2.6	0.7
F.	1.53 n. s.	2.46 n. s.	6.32**	3.07*	4.78**	2.86*
L. S. D. (P = 0.05)	0.8	1.5	0.6	0.7	7.5	1.9
Total (n = 48)	**20.0**	**37.0**	**31.0**	**27.0**	**301.0**	**152.0**

n. s. = not significant
* P = 0.05
** P = 0.01

3.3.1.2. Two weeks after compaction (December 26th, 1973)

After treatment, the one time compacted plot showed minimal vegetation damage while in the ten times compacted plot the vegetation and soil surface were disturbed.

Two weeks after treatment the total soil fauna (table 4) were significantly lower in numbers (P = 0.05) in the one time compaction experiment and highly significantly lower in numbers in both the ten times compaction and loosened soil experiments (P = 0.001) compared with the untreated control.

Numbers of Acari (table 5) were not significantly different in the one time compaction treatment but highly significant lower numbers were recorded in both the ten times compacted and loosened soil treatments (P = 0.001) compared with the control. The one time compaction experiment showed no significant difference in numbers of Mesostigmata (table 6) compared with the control, but highly significantly lower numbers of Mesostigmata were found in both the ten times compacted (P = 0.001) and loosened soil experiments (P = 0.01) compared with the control. Numbers of Prostigmata were not significantly different in the one time compaction treatment (table 7) but there were highly significantly lower numbers in both the ten times compacted loosened soil treatments (P = 0.01 each). Numbers of Cryptostigmata (table 8) were unchanged in the compacted soil but significantly greater numbers were recovered in loosened soil (P = 0.05).

Collembola (table 9) were significantly decreased in numbers in the one time compaction treatment (P = 0.05) and highly significantly decreased in both the ten times compaction and loosened soil treatments (P = 0.01) compared with the untreated control.

Other Insecta (table 10) showed no significant difference in numbers in the one time compaction or loosened soil treatments but significantly decreased in the ten times compaction treatment (P = 0.05) compared with the control.

There were no significant differences in numbers of Myriapoda in all treatments compared

3.3.1.3. One month after compaction (January 25th, 1974)

One month after treatment significant changes in total numbers of soil fauna (table 4) were not found in the one time compaction treatment, but significantly lower numbers of soil fauna were recovered in the ten times compaction and loosened soil treatments (P = 0.05) compared with the control.

Numbers of Acari (table 5) were not significantly different in the one time compaction treatment but significantly lower numbers were collected in both the ten times compacted and loosened soils (P = 0.05) compared with the untreated control. No significant difference in numbers of Mesostigmata (table 6) was found in the one time compaction experiment but significantly lower numbers were recovered in the ten times compaction and loosened soil treatments (P = 0.05) compared with the control. With Prostigmata (table 7), in the one time compacted soil the numbers remained unaltered but lower numbers were collected in the ten times compacted (P = 0.05) and loosened soils (P = 0.01) compared with the untreated control. Significant differences in numbers of Cryptostigmata in all treatments were not found compared with the control (table 8).

Collembola (table 9) also were not significantly different in numbers in all treatments compared with the untreated control.

Other Insecta (table 10) showed no significant differences in numbers in the one time compaction and loosened soil treatment but highly significant lower numbers were found in the ten times compaction treatment (P = 0.01) compared with the control.

There were no significant differences in numbers of Myriapoda (table 11) in the one time and ten times compaction treatments compared with the control. However, highly significantly higher numbers (P = 0.01) of Myriapoda were recovered in the loosened soil treatment.

3.3.1.4. Three months after compaction (March 16th, 1974)

Three months after treatment significant differences in numbers of total soil fauna (table 4) in the one time and ten times compacted soil were not found, but significantly lower numbers were recovered in the loosened soil treatment (P = 0.05) compared with the control.

Numbers of Acari (table 5) were not significantly different in the one time compacted soil although highly significantly lower numbers were collected in both the ten times compacted and loosened soils (P = 0.01) compared with the untreated control. Mesostigmata (table 6) showed no significant differences in numbers in the one time compaction treatment, but highly significantly lower numbers were found in the ten times compaction (P = 0.01) and loosened soil treatments (P = 0.05) compared with the control. Prostigmata (table 7) showed no significant differences in numbers in the one time compacted soil but significantly lower numbers in both the ten times compacted and loosened soils (P = 0.05) were recovered compared with the control. No significant difference in numbers of Cryptostigmata (table 8) in the one time and ten times compaction treatments were recorded compared with the control. However, numbers of Cryptostigmata in the loosened soil treatment were significantly higher (P = 0.05) than in the untreated control.

Neither Collembola (table 9) nor Insecta (table 10) showed any significant differences in numbers in all treatments compared with the control.

Numbers of Myriapoda (table 11) were not significantly different in the one time compacted soil and loosened soil treatments, but significantly lower numbers were found in the ten times compacted soil compared with the control ($P = 0.05$).

3.3.1.5. Six months after compaction (June 15th, 1974)

Six months after treatment the numbers of total soil fauna, Acari, Collembola and Insecta (tables 4, 5, 9 and 10) in all treatments were generally similar to the control, but significantly lower numbers ($P = 0.05$) of Mesostigmata (table 6) were recovered in the ten times compacted soil compared with the control. However, significantly higher numbers of Prostigmata (table 7) were found in the one time compaction treatment ($P = 0.01$), significantly higher numbers of Cryptostigmata (table 8) recovered in the loosened soil treatment ($P = 0.05$) and highly significantly higher numbers of Myriapoda (table 11) found in the loosened soil treatment ($P = 0.01$) compared with the control.

3.3.1.6. Nine months after compaction (September 16th, 1974)

Nine months after treatment numbers of Acari and Mesostigmata in all treatments were like those of the control (tables 5 and 6). Significantly lower numbers ($P = 0.05$) of total soil fauna (table 4) and Prostigmata (table 7) were found in the ten times compaction and loosened soil treatments compared with the untreated control. However, numbers of Cryptostigmata (table 8) in the ten times compaction treatment were significantly higher ($P = 0.05$) than in the control. Numbers of Myriapoda (table 11) in the loosened soil treatment were significantly higher ($P = 0.05$) than in the control. Collembola (table 9) and other Insecta (table 10) were significantly lower in numbers in the ten times compaction treatment ($P = 0.05$) compared with the control.

3.3.2. *Clay grassland*

3.3.2.1. Pretreatment (October 6th, 1974)

The Pretreatment samples indicated some variations between groups of soil fauna before compaction. However, the total number of soil fauna, Acari, Mesostigmata, Prostigmata, Cryptostigmata, Collembola, other Insecta and Myriapoda (tables 12—19) in either the one time or ten times pretreatment compacted plots were not significantly different compared with the control plot.

3.3.2.2. Two weeks after compaction (October 24th, 1974)

Soil compacted only once by tractor showed minimal herbage damage while that compacted ten times showed some herbage and soil surface damage.

Two weeks after the experiment started the numbers of total soil fauna in compacted and untreated (control) soil were generally unchanged (table 12). Numbers of Acari (table 13) including Prostigmata (table 15) were unaltered, but numbers of Mesostigmata (table 14) were significantly lowered ($P = 0.05$). Numbers of Cryptostigmata (table 16) were significantly lowered in the ten times compacted soil ($P = 0.05$). Numbers of Collembola (table 17) were not significantly different in the one time compacted soil, but highly significantly lowered ($P = 0.01$) in the ten times compacted soil compared with the untreated control. The number of Myriapoda (table 19) were not significantly different to that of the control, unlike the Insecta (table 18) which were highly significantly lower ($P = 0.01$).

3.3.2.3. One month after compaction (November 6th, 1974)

One month after treatment the total soil fauna (table 12) showed a highly significant decrease in numbers in both the one time and ten times compaction treatments compared with the control ($P = 0.01$).

Table 12. Effects of compaction on population and recolonization of total soil fauna in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	176.0	93.0	142.1	115.6	157.7
1× compaction	133.1 n. s.	59.8 n. s.	77.8**	146.6 n. s.	192.3 n. s.
10× compaction	136.8 n. s.	52.7 n. s.	60.3**	39.3*	112.8 n. s.
S. E. of mean	56.5	15.8	16.1	17.7	37.7
F.	0.18 n. s.	1.86 n. s.	7.20**	9.76***	1.12 n. s.
L. S. D. (P = 0.05)	162.8	45.3	46.2	50.9	108.6
Total (n = 36)	**5348.0**	**2465.0**	**3362.0**	**3617.0**	**5552.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 13. Effects of compaction on population and recolonization of Acari in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	127.8	66.3	111.1	77.8	117.8
1× compaction	105.2 n. s.	44.5 n. s.	68.8 n. s.	112.4 n. s.	162.7 n. s.
10× compaction	110.0 n. s.	46.7 n. s.	50.5**	29.3*	45.0*
S. E. of mean	45.4	12.9	15.6	12.9	24.8
F.	0.07 n. s.	0.87 n. s.	3.98*	10.48***	5.74**
L. S. D. (P = 0.05)	130.8	37.1	44.8	37.2	71.4
Total (n = 36)	**4115.0**	**1889.0**	**2765.0**	**2634.0**	**3906.0**

n. s. = not significant
* P = 0.005
** P = 0.01
*** P = 0.001

Table 14. Effects of compaction on population and recolonization of Mesostigmata in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	32.0	26.5	26.1	11.8	11.1
1× compaction	23.6 n. s.	7.3*	12.9*	11.7 n. s.	6.3 n. s.
10× compaction	19.8 n. s.	5.8*	5.2**	3.1***	4.4 n. s.
S. E. of mean	6.9	5.4	6.0	1.7	2.4
F.	0.82 n. s.	4.50*	6.30**	8.80***	2.01 n. s.
L. S. D. (P = 0.05)	19.9	15.7	12.1	4.9	7.0
Total (n = 36)	**905.0**	**476.0**	**530.0**	**319.0**	**262.0**

n. s. = not significant
* P = 0.05
* P = 0.01
*** P = 0.001

Table 15. Effects of compaction on population and recolonization of Prostigmata in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	43.6	24.3	38.8	55.8	95.7
1× compaction	34.5 n. s.	28.4 n. s.	28.0 n. s.	70.3 n. s.	140.2 n. s.
10× compaction	69.1 n. s.	38.2 n. s.	28.7 n. s.	16.9**	26.9*
S. E. of mean	15.3	6.5	5.6	9.8	21.9
F.	1.38 n. s.	1.2 n. s.	0.32 n. s.	7.93**	6.82**
L. S. D. (P = 0.05)	44.0	18.7	16.0	28.2	62.9
Total (n = 36)	**1766.0**	**1090.0**	**1085.0**	**1717.0**	**3153.0**

n. s. = not significant
* P = 0.05
** P = 0.01

Table 16. Effects of compaction on population and recolonization of Cryptostigmata in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	52.2	15.5	51.3	10.2	11.1
1× compaction	47.1 n. s.	8.8 n. s.	27.9 n. s.	30.4 n. s.	16.2 n. s.
10× compaction	21.1 n. s.	3.5*	16.7 n. s.	9.3 n. s.	13.7 n. s.
S. E. of mean	27.9	3.9	12.3	7.0	6.5
F.	0.36 n. s.	2.34 n. s.	2.07 n. s.	2.90 n. s.	0.15 n. s.
L. S. D. (P = 0.05)	80.3	11.3	35.3	20.3	18.7
Total (n = 36)	**1440.0**	**333.0**	**1159.0**	**598.0**	**491.0**

n. s. = not significant
* P = 0.05

Table 17. Effects of compaction on population and recolonization of Collembola in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	42.1	22.8	22.9	33.7	37.1
1× compaction	22.6 n. s.	12.4 n. s.	5.9**	30.9 n. s.	26.0 n. s.
10× compaction	20.8 n. s.	4.8**	7.6**	6.1*	59.0 n. s.
S. E. of mean	12.4	4.2	3.5	9.2	18.9
F.	0.91 n. s.	4.66*	7.02**	2.73 n. s.	0.79 n. s.
L. S. D. (P = 0.05)	35.7	12.0	10.2	26.5	54.3
Total (n = 36)	**1025.0**	**480.0**	**437.0**	**848.0**	**1465.0**

n. s. = not significant
* P = 0.05
** P = 0.01

Table 18. Effects of compaction on population and recolonization of other Insecta in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	5.8	3.4	7.7	3.8	2.5
1× compaction	4.9 n. s.	2.8 n. s.	2.8*	2.3 n. s.	3.6 n. s.
10× compaction	5.5 n. s.	0.9**	2.1*	3.8 n. s.	8.8***
S. E. of mean	0.9	0.5	1.5	0.8	1.1
F.	0.22 n. s.	6.03**	3.91*	1.16 n. s.	8.69***
L. S. D. (P = 0.05)	2.7	1.5	4.4	2.3	3.3
Total (n = 36)	**194.0**	**85.0**	**151.0**	**119.0**	**178.0**

n. s. = not significant
* P = 0.05
** P = 0.01
*** P = 0.001

Table 19. Effects of compaction on population and recolonization of Myriapoda in clay grassland soil (mean of 12 replicates)

Treatment	Pretreatment	After treatment			
		two weeks	one month	three months	six months
	6/10/74	24/10/74	6/11/74	7/1/75	7/4/75
Control	0.3	0.5	0.4	0.3	0.3
1× compaction	0.4 n. s.	0.2 n. s.	0.3 n. s.	0.1 n. s.	0.0*
10× compaction	0.5 n. s.	0.3 n. s.	0.1 n. s.	0.2 n. s.	0.0*
S. E. of mean	0.2	0.2	0.2	0.1	0.1
F.	0.40 n. s.	1.34 n. s.	1.09 n. s.	0.40 n. s.	3.67*
L. S. D. (P = 0.05)	0.6	0.4	0.5	0.4	0.2
Total (n = 36)	**14.0**	**11.0**	**9.0**	**6.0**	**3.0**

n. s. = not significant
* P = 0.05

Table 20. Effects of compaction on number, weight and recolonization of earthworms in silt loam grassland soil (mean of 4 replicates/0.09 m²)

Treatment	After treatment			
	No. of earthworms		Wt. of earthworms (g)	
	four months	ten months	four months	ten months
	7/4/74	1/10/74	7/4/74	1/10/74
Control	4.0	35.8	7.5	12.7
1× compaction	10.0 n. s.	33.5 n. s.	2.8 n. s.	12.1 n. s.
10× compaction	2.0 n. s.	20.0***	0.6*	6.6 n. s.
Loosened soil	1.8 n. s.	12.3***	2.5 n. s.	10.1 n. s.
S. E. of mean	2.1	1.1	2.1	3.1
F.	3.30 n. s.	114.23***	1.64 n. s.	0.79 n. s.
L. S. D. (P = 0.05)	6.5	6.5	6.4	9.5

n. s. = not significant
* P = 0.05
*** P = 0.001

Table 21. The effects of compaction on number, weight and recolonization of earthworms in clay grassland (mean of 4 replicates/0.09 m²)

Treatment	After treatment	
	No. of earthworms	Wt. of earthworms (g)
	six months 25/4/75	six months 25/4/75
Control	19.0	8.6
1× compaction	19.0 n. s.	7.7 n. s.
10× compaction	8.5 n. s.	4.2 n. s.
S. E. of mean	3.6	2.1
F.	2.77 n. s.	1.16 n. s.
L. S. D. (P = 0.05)	11.7	6.8

n. s. = not significant

Numbers of Acari (table 13) showed no significant and highly significant (P = 0.01) decreases in the one time and ten times compaction treatments respectively compared with the untreated control. There were significantly lower numbers of Mesostigmata (table 14) in the one time compaction treatment (P = 0.05) and highly significantly lower numbers (P = 0.01) in the ten times compaction treatment compared with the control. Numbers of Prostigmata in both treatments remained unchanged compared with the control (table 15) as were the Cryptostigmata (table 16).

Numbers of Collembola (table 17) were highly significant lower in both the one time and ten times compaction treatments (P = 0.01) compared with the untreated control.

The remaining Insecta (table 18) were significantly lowered (P = 0.05) in both treatments compared with the control, but the numbers of Myriapoda (table 19) were not.

3.3.2.4. Three months after compaction (January 7th, 1975)

There were no significant changes in total numbers of soil fauna (table 12) in the one time compacted soil, but significantly lower numbers were recovered in the ten times compaction treatment (P = 0.05) compared with the control.

Numbers of Acari (table 13) showed no significant and significantly lower numbers (P = 0.05) in the one time and ten times compaction treatments respectively. There were highly significantly lower numbers of Mesostigmata in the ten times compaction treatment (P = 0.001) compared with the control (table 14). Prostigmata (table 15) showed highly significantly lower numbers in only the ten times compaction treatment (P = 0.01) compared with the untreated control. However, numbers of Cryptostigmata (table 16) were not significantly different with both treatments.

Numbers of Collembola (table 17) were significantly lower only in the ten times compacted soil compared with the control (P = 0.05. Significant differences in either the remaining Insecta (table 18) or Myriapoda numbers (table 19) were not found.

3.3.2.5. Six months after compaction (April 7th, 1975)

Six months after treatment numbers of total soil fauna (table 12), Mesostigmata (table 14), Cryptostigmata (table 16) and Collembola (table 17) were not significantly different in both treatments compared with the control, but the numbers of other Insecta in the ten times compacted soil (table 18) were significantly greater (P = 0.001).

Numbers of Acari (table 13) remained significantly lower only in the ten times compaction treatment (P = 0.05) compared with the control, as were the Prostigmata (P = 0.05) (table 15).

Myriapoda (table 19) were significantly lower in numbers in both treatments (P = 0.05) compared with the untreated control.

3.4. Effects of compaction on earthworms

3.4.0. *Remark*

The effects of compaction on the number and body-weight of earthworms in silt loam and clay grassland are given in tables 20 and 21.

3.4.1. *Silt loam grassland*

Four months after compaction (7th April, 1974; table 20) significant differences in numbers of earthworms were not found with all treatments compared with the control. Although significant differences in weight of earthworms were not recorded in the one time compacted and loosened soils, significantly lower weights in ten times compacted soil were found ($P = 0.05$) compared with the control.

Ten months after treatment (1st October, 1974; table 20) highly significantly lower numbers of earthworms were collected from both the ten times compacted and loosened soils ($P = 0.001$) but not from the one time compacted soil. However, significant differences in the body-weight of the worms were not found in all treatments compared with the untreated control.

3.4.2. *Clay grassland*

Six months after treatment (25th April, 1975; table 21), although only half the number of earthworms were recovered in ten times compacted soil compared with the control, the results were not significant. Body-weight differences in both treatments were also not significant.

3.5. Treatment effects on soil physical conditions

3.5.1. *Silt loam grassland*

Generally, differences in soil physical properties (fig. 1) between the treatments were small and not statistically significant. However, at a depth of 0—7.6 cm the loosening soil treatment gave initially a bulk density significantly lower than the other three treatments. However, this low bulk density had increased when the soil had dried out 190 days after treatment application. Over the same period, the relatively high bulk densities of the other three treatments decreased and, after 190 days, differences between the four treatments were negligible. When compared to the other treatments a higher moisture content and air porosity, but lower mechanical resistance, was associated with the loosened soil at 0—7.6 cm. Differences in mechanical resistance showed most clearly 190 days after treatment when the soil had dried.

The loosening by rotary cultivation to a depth of about 8 cm seemed to result in an increase in bulk density (7.6—15.2 cm depth) immediately below the depth of working although differences were not statistically significant. Differences in mechanical resistance again showed most clearly 190 days after treatment. Other differences between treatments in soil physical properties were small and not significant.

3.5.2. *Clay grassland*

Again, generally differences in soil physical properties between the treatments were small and not statistically significant (fig. 2). It is evident at both 0—7.6 and 7.6—15 cm depths, however, that the two compaction treatments resulted in slightly higher bulk densities, lower air porosities and higher mechanical resistance.

4. Discussion

4.0. Prefactory note

This work assessed the effects of compaction in the field of two different types of agricultural soils on Wye College Farm on soil fauna. The effects of loosened soil in the field on soil fauna were also found. The soil fauna of silt loam grassland and clay grassland gene-

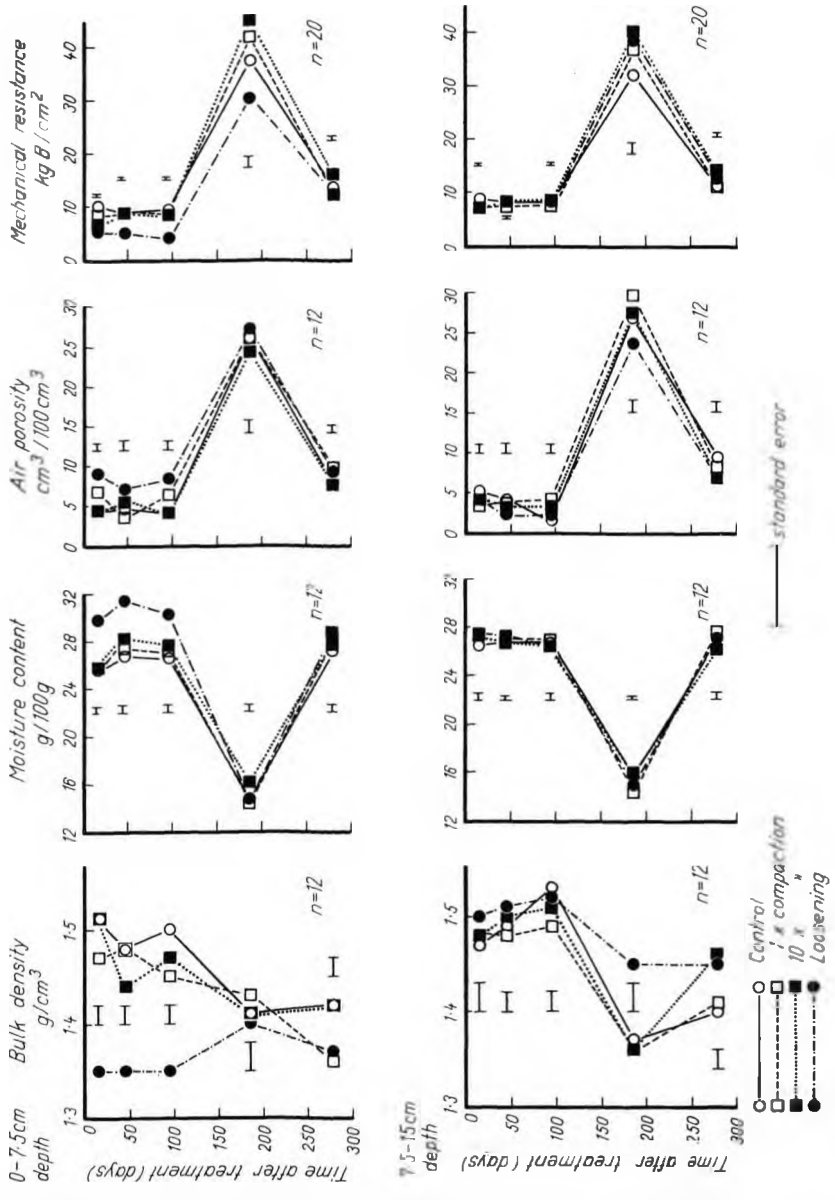

Fig. 1. The effects of compaction treatments and time on soil physical conditions: Silt loam grassland. Sampling dates: 27. 12. 73, 26. 1., 17. 3., 16. 6. and 17. 9. 74. Originally drawn by a computer controlled graph-plotting instrument.

rally had relatively low numbers of both individuals and diversity of species (ARITAJAT 1975), presumably because both sites were ley grassland and had recently been seeded. Although loosening of soil seemed to give more favourable soil physical conditions, the faunal population was found to be low, presumably as a result of mechanical damage to animals by the rotary cultivation. FRANCÉ (1912) found that the soil faunal population declined to one-tenth of its original level after ploughing.

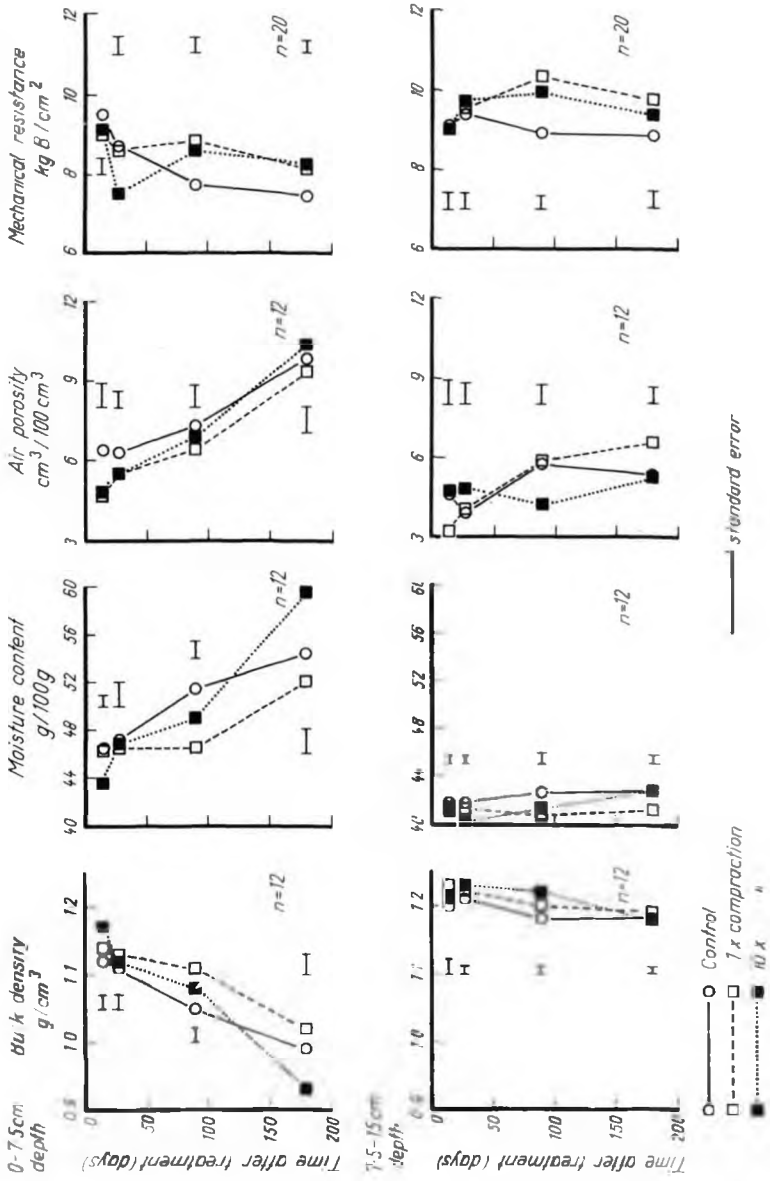

Fig. 2. The effects of compaction treatments and time on soil physical conditions: Clay grassland. Sampling dates: 25. 10. and 7. 11. 74, 8. 1. and 8. 4. 75. Note see fig. 1.

4.1. Effects of soil compaction on soil arthropods in the field and recovery from compaction

Following compaction of silt loam grassland two weeks after treatment some members of the soil faunal population were altered. When compacted once (by tractor) significantly lower numbers of soil fauna were found, mainly due to a decline in numbers of Collembola. With ten times compaction, highly significantly lower numbers of soil fauna were obtained, owing to decreases in numbers of Acari (Mesostigmata and Prostigmata), Collembola and other Insecta. On the loosened soil treatment in the same area, highly significant lower numbers of soil fauna were recovered, mainly Acari (Mesostigmata and Prostigmata) and

Collembola. One month after treatment, most of the fauna in soil compacted once had recovered, although in the ten times and loosened soils some groups of Acari were still generally lower than in the untreated control.

In clay soil, the effects of compaction after two weeks showed that the total numbers of soil fauna generally remained unchanged, although there were alterations in numbers of some groups of soil fauna. For example, the number of Mesostigmata was significantly decreased after being compacted once. Numbers of Mesostigmata, Cryptostigmata, Collembola and other Insecta also decreased in the ten times compacted soil. One month after treatment following one time compaction, the number of soil fauna remained significantly lower, owing mainly to the decline in numbers of Mesostigmata, Collembola and other Insecta. The ten times compacted treatment also resulted in a highly significant reduction in numbers of soil fauna, owing to decreased numbers of Mesostigmata, Collembola and other Insecta.

Different taxonomic groups of soil fauna in both sites thereafter gradually recovered from the effects of compaction. In silt loam grassland, the results were generally not significantly different in the one time compacted soil three months after treatment compared with the control, and also in ten times compaction and loosened soil treatments six months after treatment. In clay grassland, the results were not significantly different in the one time compacted soil three months after treatment, and usually in the ten times compacted soil six months after treatment.

The effect of compaction treatments on soil physical conditions were small except in the mechanical resistance of silt loam 190 days after treatment, when the soil had dried out. This increase in treatment difference with time is thought to be due to the effect on mechanical resistance of the interaction between bulk density and soil moisture (Gooderham and Fisher 1975). It is concluded that the reduction of faunal populations by compaction was not due to marked adverse changes in soil physical conditions, but was probably due to direct mechanical damage to the soil animals.

Very little other work has been done on the effects of compaction on soil arthropods. The results obtained in present studies may be compared with those of Morris (1968) and Chapell et al. (1971) which appear to be the only investigations made on the effects of compacted soils on soil fauna. Chapell et al. (1971) found that on chalk grassland, at Farley Mount near Winchester, Hants., activitity by public trampling (pedestrians and motor vehicles) and sheep resulted in three zones of compaction: light, moderate and heavy trampling. The heavy trampled zone had comparatively lower numbers of Acari, Collembola and other Insecta compared with the lightly and moderately trampled zone. For example, in heavy, moderate and lightly trampled soil the ratio of Acari was 1: 6: 10.8 respectively and that of Collembola 1: 1.3: 6 respectively. Morris (1968) found that on the chalk grassland, at Barton Hills, Bedfordshire, most of the larger arthropod population occurred more abundantly on grassland ungrazed for 2—3 years than on an intensively sheep-grazed site. Morris (1968) did not attempt to recover Acari and Collembola from these sites. The ungrazed site supported more species and individuals of Coleoptera in winter than in summer, and Morris (1968) considered that these differences were due to the more abundant quantities of plant food which were then available in ungrazed grassland and also the higher relative humidity and more stable microclimate.

4.2. Effects of field soil compaction on earthworms and recovery from compaction

Although the effects of soil compaction in the field were expressed both as changes in numbers and body-weight, Edwards and Lofty (1972) suggested that weight (biomass) was a more important measurement. In silt loam grassland the body-weight of earthworms significantly decreased in ten times compacted soil four months after treatment, but changes were not found in one time compacted or loosened soils. Ten months after treatment, however, significant differences in weight were not recorded between any treatment. In clay soil six months after compaction the body-weight of earthworms remained unaltered. Zicsi (1958) stated that cultivation after harvest had drastic effects on earthworm populations, decreasing the surface-living species.

5. Summary

(1) The efficiency of an air-conditioned (Tullgren) apparatus for extracting soil arthropods from two soil types was investigated. This method was appreciably more efficient than the modified Salt and Hollick flotation method. Soil arthropods were extracted within 14 days.

(2) The overall population of total soil fauna, including Acari, Collembola, other Insecta and Myriapoda in silt loam and clay grassland at Wye College were estimated.

The effects of compaction of agricultural soil by tractor on soil fauna were assessed at different intervals in the loam grassland on soil fauna were also investigated. In silt loam soil, two weeks after treatment, the one time compacted soil sometimes had significantly lower numbers of soil fauna, particularly Collembola. In ten times compacted and loosened soils highly significantly decreases in arthropods, mainly Acari and Collembola, were recorded. After one month the effects remained obvious although less so with one time compacted soil. In clay soil after two weeks' compaction, some groups of the soil fauna decreased but after one month these effects were more pronounced, particularly with Acari and Collembola.

In silt loam grassland, recovery of the soil fauna from the effects of compaction began one month after treatment in the one time compacted soil and three months after treatment in the ten times compacted and loosened soils, but recovery was not completed until at least six months afterwards. In clay grassland, recovery of soil fauna from the effects of compaction took three months for the one time compacted soil and at least six months for the ten times compacted soil.

(3) The effects of soil compaction significantly reduced the body-weight (and numbers) of earthworms in the ten times compacted silt loam grassland soil four months after treatment, but the population recovered ten months after treatment. Loosened soil had a smaller effect, while soil compacted once had none. Earthworms were not effected after six months in compacted clay soil.

(4) Treatment effects on various soil physical conditions were also made.

(5) The results are compared with other work on compaction.

6. Acknowledgements

We thank Mr. A. G. Clewer and Mr. P. A. Kentish (Wye College) for advice on statistical problems and computer work. We are grateful to Dr. J. A. Wallwork (Westfield College, University of London) for criticizing the manuscript, and to the Ford Foundation for financial support (U. A.).

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8. Appendix: Lists of taxonomic groups identified

Collembola

Isotoma notabilis (SCHAFFER), *Isotoma viridis* BOURLET, *Isotoma productus* (AXELSON), *Folsomia* sp., *Lepidocyrtus cyaneus* TULLBERG, *Pseudosinella alba* (PACKARD), *Entomobrya* sp., *Orchesella* sp., *Sminthurides pumilis* (KRAUSBAUER), *Sminthurus viridis* LINN., *Sminthurinus* sp., *Tullbergia* sp., *Onychiurus* sp., *Hypogastrura denticulata* (BAGNALL), *Brachystomella parvula* (SCHAFFER), *Friesea* sp.

Acari

Mesostigmata

Pergamasus longicornis BERL., *Pergamasus mirabilis* WILLM., *Pergamasus cambriensis* BHATTACHARYYA, *Pergamasus armatus* HALBERT, *Holoparasitus* sp., *Rhodacarus roseus* OUDS., *Rhodacarellus silesiacus* WILLM., *Pachylaelaps furcifer* OUDEMANS, *Alliphis halleri* (G. et R. COM), *Macrocheles carinatus* (C. L. K.), *Ameroseius* sp., *Uropoda* sp.

Prostigmata

Eupodidae 3 spp., *Scutacarus* sp., *Siteroptes* sp., *Tarsonemus* sp., *Balaustium* sp., *Bdella* sp., *Rhagidia* sp., *Tydeus* sp.

Astigmata

Tyrophagus sp.

Cryptostigmata

Eupelops sp., *Scheloribates* 2 spp., *Oppia* 2 spp., *Achipteria* sp., *Minunthozetes* sp., *Hemileius* sp.

Myriapoda

Chilopoda

Geophilus sp., *Lithobius* sp.

Diplopoda

Polydesmus sp., *Blaniulus* sp.

Symphyla

Scutigerella sp., *Symphylella* sp.

Pauropoda

Allopauropus sp.

Also found were several species of Lumbricidae, Coleoptera larvae, Diptera larvae, Hemiptera Psocoptera, Lepidoptera larvae and Protura (Acarentomidae Gen. sp.).

We thank Dr. R. C. CLUTTERBUCK for his help in identifying some of the material.